Comparative Simulation of Both PSO and GWO Algorithms Based MPPT Technique for PV Module under MATLAB/Simulink

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ABSTRACT

Solar panels, also known as photovoltaic (PV) panels, indeed play a significant role in the global energy supply by converting sunlight into electrical energy through the photovoltaic effect. This process involves the generation of electric current when sunlight interacts with the semiconductor material in the solar cells. The efficiency of solar panels in converting sunlight into electricity is influenced by various factors, including the intensity of sunlight, temperature, and the characteristics of the solar cells themselves. High levels of sunlight intensity and lower temperatures typically lead to better efficiency. One crucial advancement in solar panel technology is the development of Maximum Power Point Tracking (MPPT) technique. This strategy seeks to maximize the solar panels' overall output and efficiency. With MPPT technology, solar panels are guaranteed to run at their Maximum Power Point (MPP). This particular point denotes the ideal state in which, under particular circumstances, the panel produces the most electricity. In order to accomplish this optimization, MPPT systems continually modify the voltage and current of the solar panels in response to shifting environmental conditions. This work compares, the performance of two different MPPT algorithms: the Particle Swarm Optimization (PSO) strategy and the Grey Wolf Optimization (GWO) strategy using Matlab/Simulink 2019a version.

I. Introduction

Renewable energy sources, notably solar photovoltaic (PV) systems, have drawn substantial research interest owing to their capacity to directly transform light into electric power. These innovative technologies are experiencing a surge in global adoption, heralded for their environmentally conscious nature, cleanliness, and remarkable resilience. In contrast to conventional energy sources such as fossil fuels, they stand out as sustainable alternatives with the potential to mitigate environmental impact. However, the utilization of Solar PV modules still has several limitations. These include the sporadic nature and low photo-conversion efficiency. The efficiency of converting sunlight into usable electrical power typically stay below 17%. Additionally, the electricity generated by these modules fluctuates due to varying weather conditions, such as changes in irradiance and ambient temperature, further affecting their overall performance [1], [2], [3]. To improve photovoltaic (PV) systems' efficiency, the Maximum Power Point Tracking (MPPT) method's application has been the subject of in-depth scientific investigation [4]. This method's primary goal is to extract the PV module's maximum output power at various temperatures and sun radiation levels [5]. Many MPPT strategies, including the Perturb and Observe (P&O), Incremental Conductance (IC), Grey Wolf Optimization (GWO), Practical Swarm Optimization (PSO), Fuzzy Logic and Announcement (ANN) methods, and others, have been proposed recently [6], [7]. This survey presents and compares the GWO and PSO algorithms based on MPPT under various atmospheric conditions.

The remaining portions of the paper are organized as follows. Section 2 presents the features of the PV panel and the mathematical modeling. The comprehensive PSO and GWO MPPT algorithms are presented in Section 3. Section 4 discusses the simulation results of PV arrays, MPPT algorithms, and their comparison. Section 5 concludes the paper with some last thoughts.

II. Ideal Photovoltaic Cell

When exposed to photons, or light particles, an electronic component known as a photovoltaic (PV) cell, sometimes called a solar cell, produces energy. A solar module is made up of several solar cells connected in parallel circuits. After that, these modules are connected to form a solar panel. These solar panels are often installed in groups known as arrays or systems.

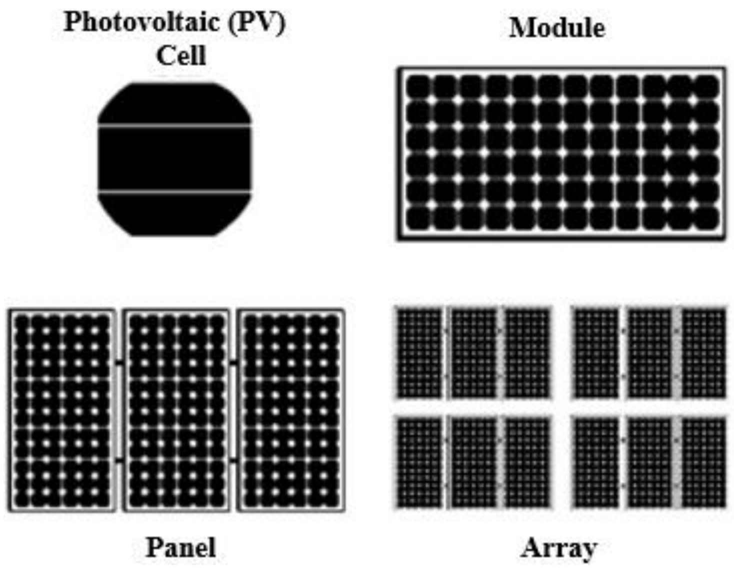

Figure 1. PV system from cell to arry.

An analogous electric circuit can be used to represent any PV element, including individual PV cells, modules, and complete arrays [8]. The corresponding circuit is depicted in Fig. 2 and consists of a current source that is reliant on light, a p-n junction diode, and series and parallel resistances. The PV cell's single diode equivalent circuit is the name given to this model. A detailed discussion of the circuit description and its full mathematical modelling may be found in [9].

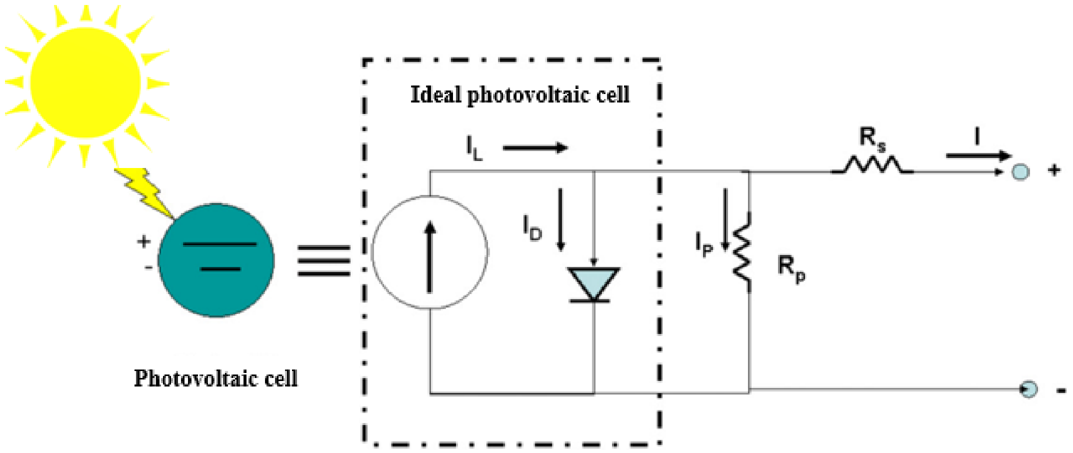

Figure 2. Equivalent model of solar cell: A current source and a diode are connected in parallel. A series resistance (Rs) and a shunt resistance (Rp) are also added because, in reality, no solar cell is perfect.

Table 1 displays the parameters used in this paper as well as the features of the PV module.

Table 1. Standard test conditions (STC) of the Kyocera solar KC200GT module.

Maximum PV Power	P_{MAX}=200.143W
MPP Voltag	V_{MPP}=26.3V
MPP Current	I_{MPP}=7.61A
Open-Circuit Voltage	V_{OC}=32.9V
Short-Circuit Current	I_{SC}=8.21A
Temperature coefficient of V_{OC}	*-0.35502*
Temperature Coefficient of I_{SC}	*0.06*
Number of cells	*54*

The variation of the atmospheric terms affects the photovoltaic cell's nonlinear characteristic. A power converter switch needs to be managed by a particular algorithm in order to track the maximum power point because the peak power point is highly dependent on weather conditions [10]. The PV array's P-V and I-V curves are displayed in Fig.3 while it operates at various temperatures and with a uniform solar irradiation of 1000 W/m^2. Fig.4 displays the P-V and I-V curves at various irradiances and a constant temperature of 25 ◦C.

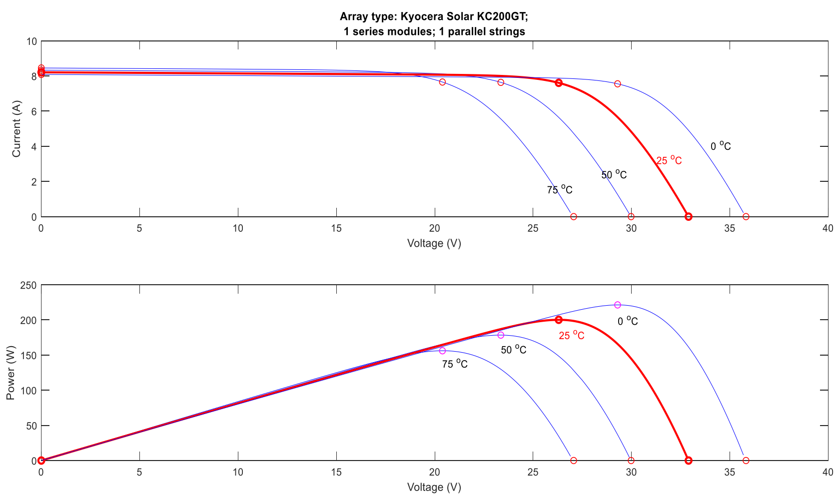

Figure 3. I-V and P-V curves at 1000W/m^2 and variable temperature for the Kyocera Solar KC200GT.

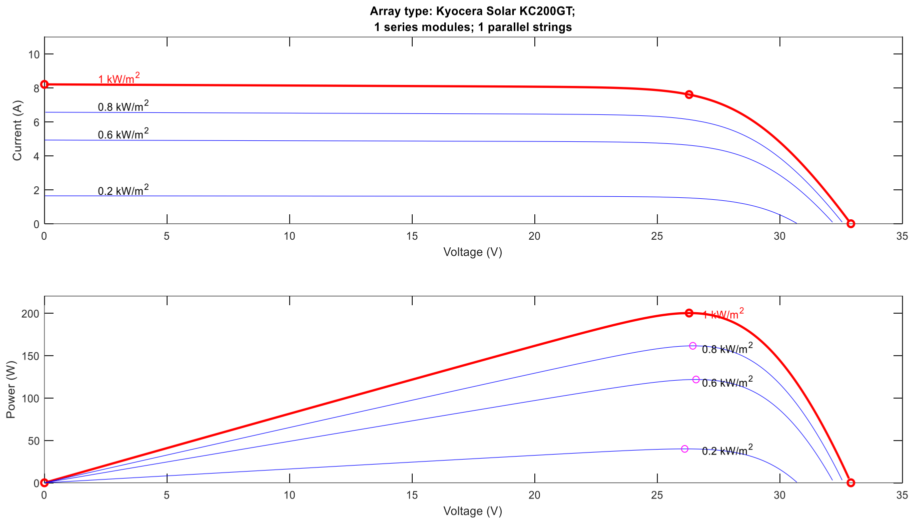

Figure 4. I-V and P-V curves at 25 °C and variable irradiance for the Kyocera Solar KC200GT.

In Fig.3, the maximum power and the open circuit voltage both drop with increasing ambient temperature at a constant solar irradiance. In Fig.4, the current increases for the same voltage at a constant temperature of 25 ◦C due to an increase in sun irradiation. As solar irradiance increases, the solar PV power grows nonlinearly. As a result, low ambient temperature and high sun irradiation are the ideal climate conditions for solar photovoltaic cells.

III. MPPT techniques

Maintaining the PV panel voltage around the MPP voltage is the main objective of the MPPT algorithm in a photovoltaic system [11], [12]. MPPT approaches have been the subject of comparative evaluations by numerous researchers [13], [14], [15], [16]. This section presents the two MPPT methods that are the subject of this study. They are both used to track the MPP in the PV array under conditions of constant temperature and irradiance.

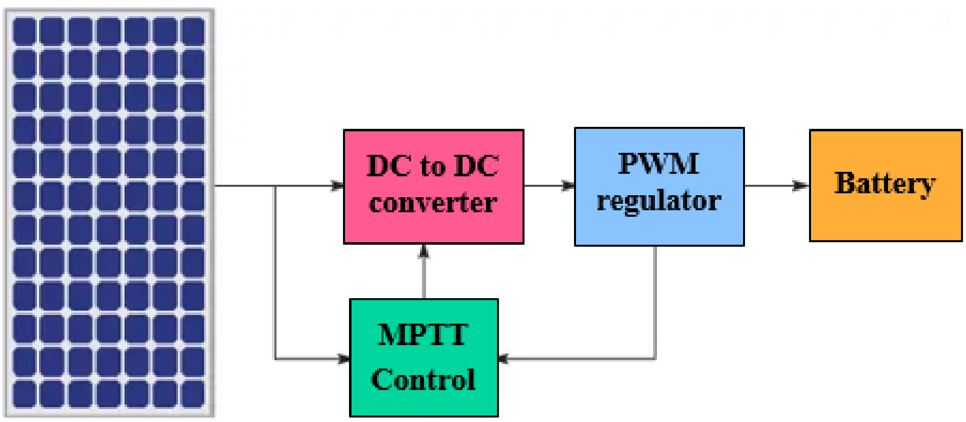

Figure 5. Diagram of MPPT controller.

III.1. PSO algorithm

Eberhart and Kennedy created the Particle Swarm Optimization (PSO) theory of intelligence optimization in 1995. This algorithm's core idea was motivated by the way fish and birds forage in schools, and it seemed to simplify search and optimization issues that were connected to more traditional ones. In order to find the optimal solution, each particle in the algorithm maintains track of its position and fitness inside the search space, which is based on a search technique by a single population. Each individual position designated as a particle is modified on a regular basis. Every contact in the PSO algorithm corresponds to a change in the particle's velocity, which approximates the optimal solution both locally and globally. For every example, the acceleration parameter is independent and random [17], [18]. In this work, the inertia weight (w) is defined as 0.1, the personal learning coefficient c_1 is set at 1.5, the global learning coefficient c_2 is set at two. The flowchart of the PSO-based MPPT method is presented in Fig. 6.

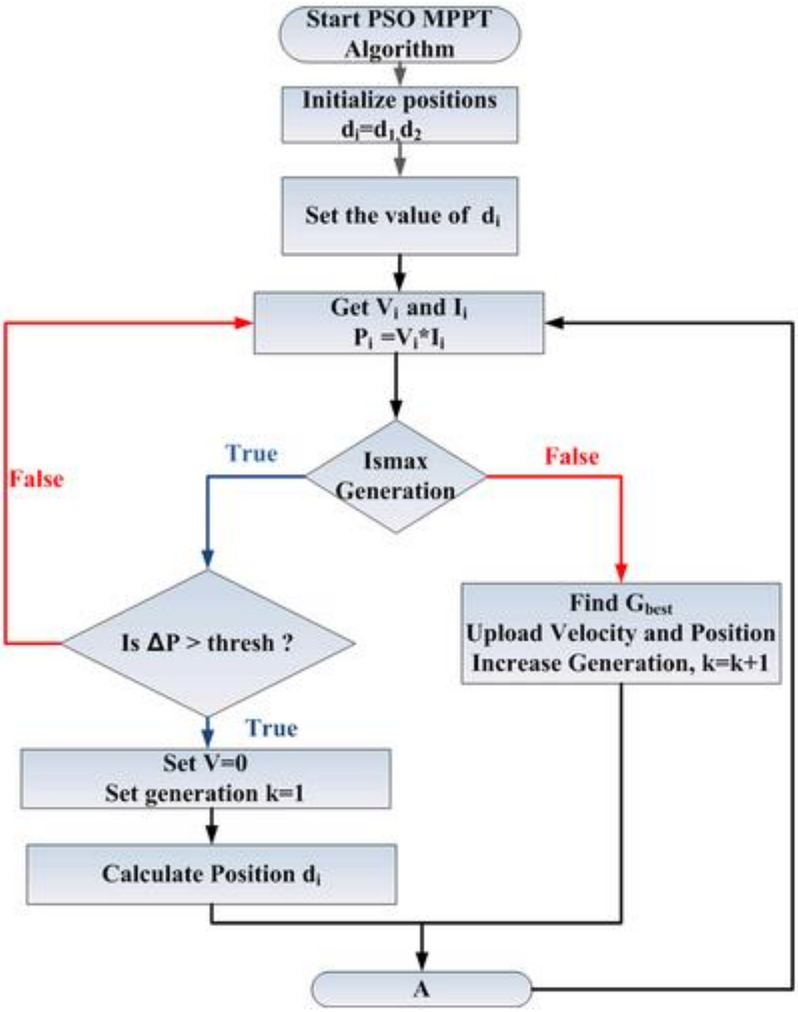

Figure 6. Flowchart for the PSO based MPPT.

III.2. GWO algorithm

The Grey Wolf Optimization Algorithm (GWO) is a swarm-based optimization technique that draws inspiration from the grey wolf's hunting process and leadership structure. The algorithm uses four sorts of wolves (alpha, beta, gamma, and omega) to assemble the hierarchy in order to imitate social behavior [19]. The wolves denoted by α, β, δ, and ω stand for the pyramid leadership structure, wherein α leads the search area, with assistance from β and δ leaders, and ω, the remaining wolves, following the leaders in turn. Fig. 7 illustrates the flowchart for the GWO-based MPPT approach.

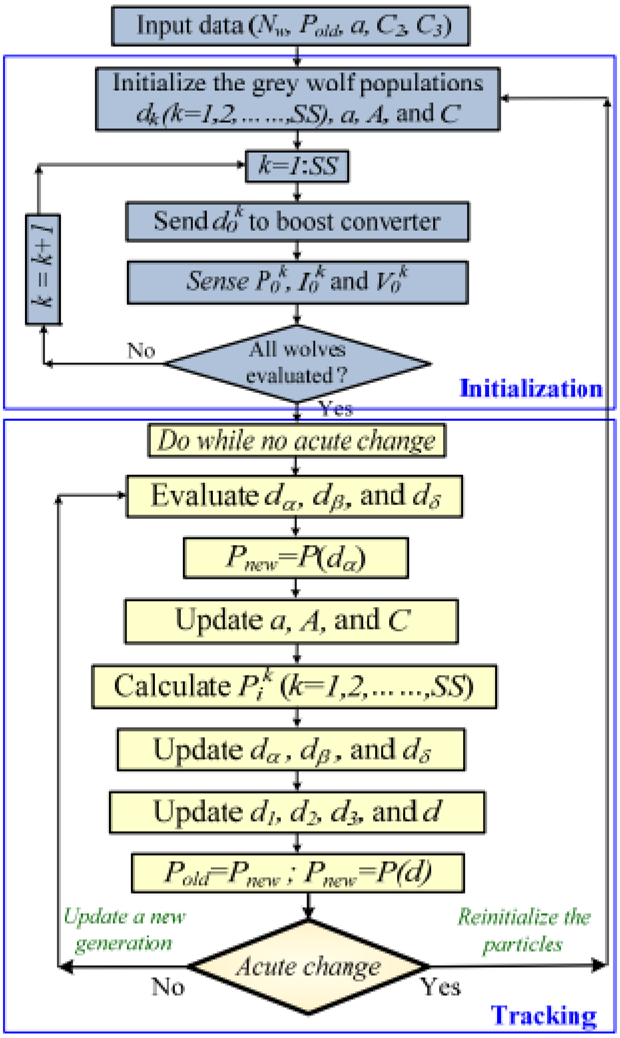

Figure 7. Flowchart for the GWO based MPPT.

IV. Sumilation And Results

The simulation model made with MATLAB/Simulink is displayed in Fig. 8. The application of PSO and GWO techniques for the MPPT tracker's implementation was investigated in this study. Efficiency is the main criterion used to forecast the viability of the MPPT plan.

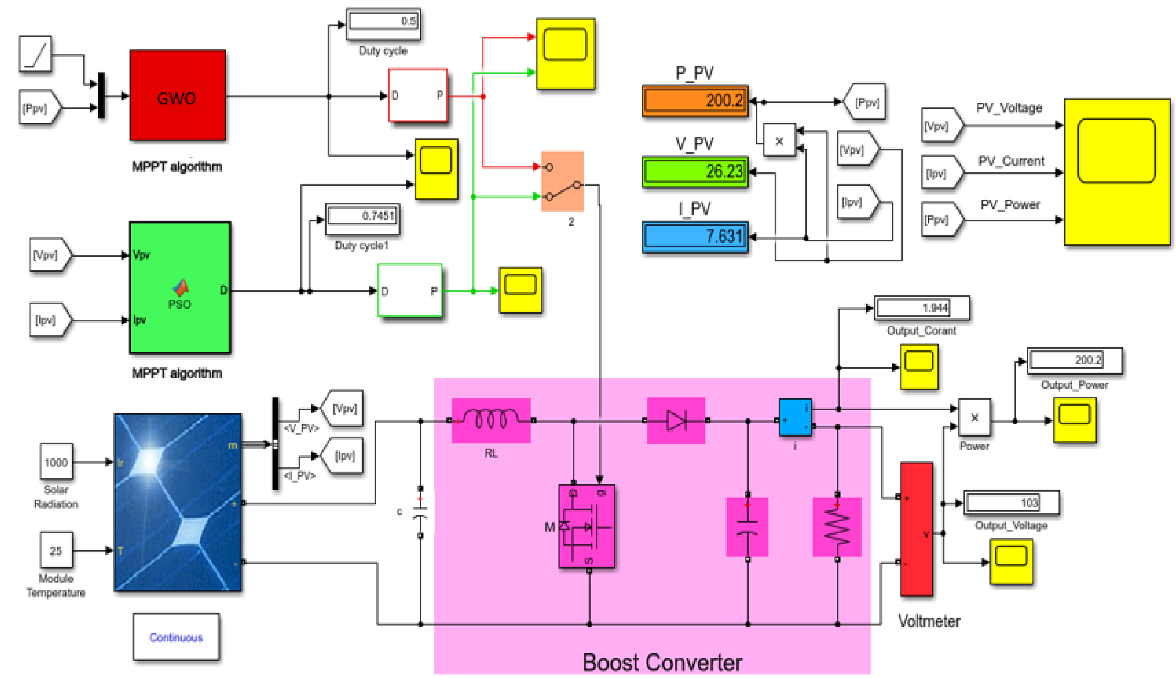

Figure 8. Simulink/matlab of PSO and GWO based MPPT block diagram.

Three separate scenarios are examined in order to make the comparison of the offered algorithms easier. In the first scenario, where solar panels are evaluated at 25°C and exposed to 1000 W/m^2 of solar irradiation, the PV module is assumed to be operating at Standard Test Condition (STC). Fig.9 and Fig.10 show the outcomes of the simulation.

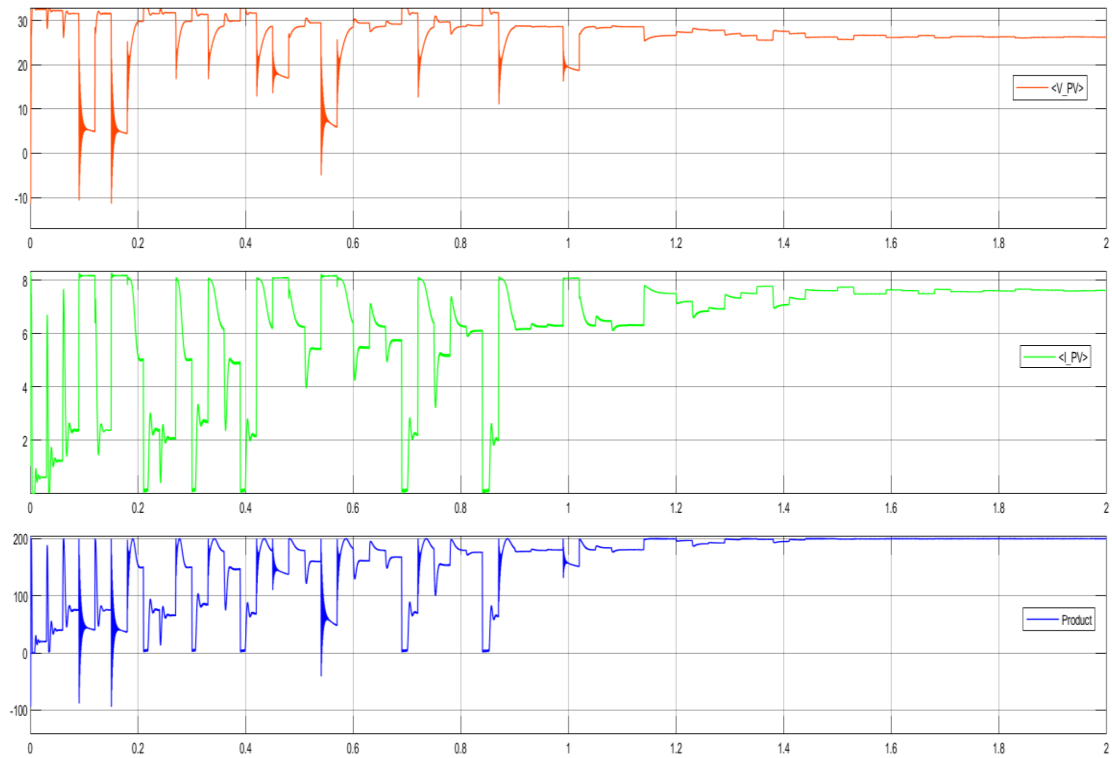

Figure 9. Results of PSO based MPPT simulation under STC condition.

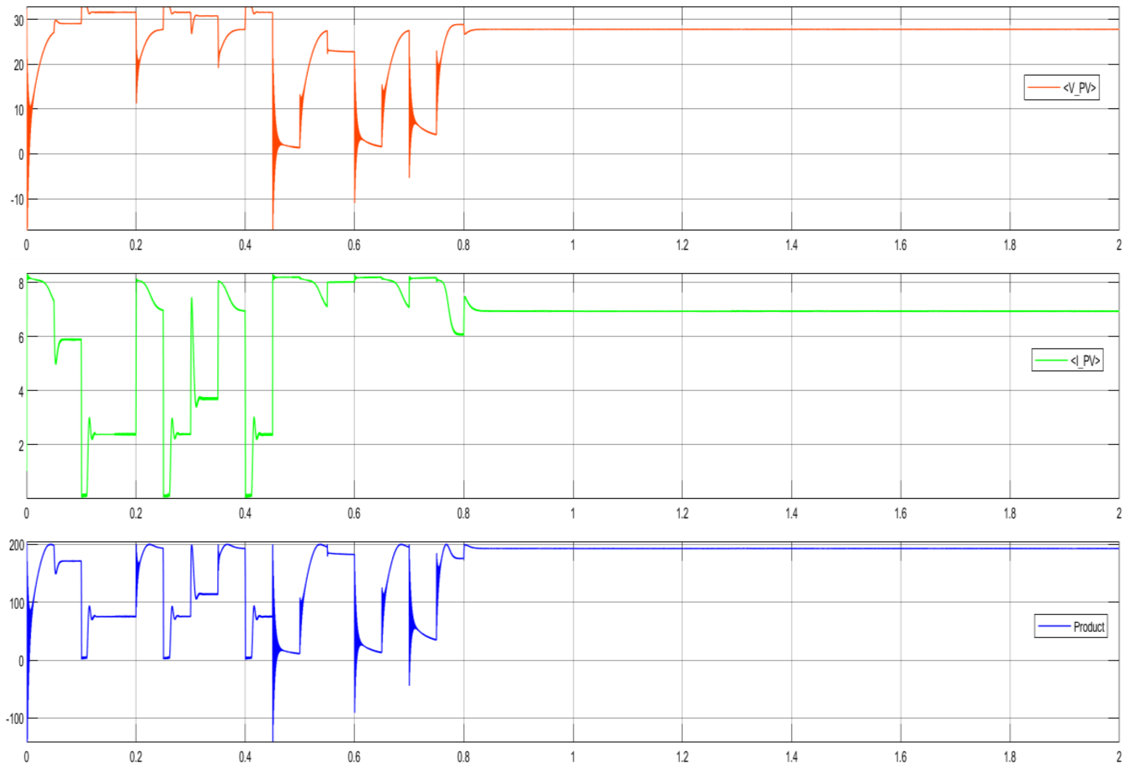

Figure 10. Results of GWO based MPPT simulation STC condition.

It is evident that both MPPT algorithms successfully reached to the MPP. The GWO based MPPT algorithm exhibited a faster convergence with fewer iterations attain the MPP, resulting in a shorter settling time. However, this came at the expense of a slightly low accuracy. On the other hand, the maximum power point tracking accuracy of the PSO-based MPPT was higher, although exhibiting more power oscillation.

The simulation results for the second scenario, which are shown in tables 2 and 3, are obtained at 1000 W/m^2 under various temperatures.

Table 2. PSO simulation results with variant temperature at 1000 w/m^2 irradiance.

Temperature °C	P [KW]	Duty cycle	Time to reach the MPP
75	*156.2*	*0.7754*	*1.472*
50	*178.3*	*0.7598*	*1.415*
25	*200.2*	*0.7451*	*1.441*
0	*221.4*	*0.7293*	*1.299*

Table 3. GWO simulation results with variant temperature at 1000 w/m^2 irradiance.

Temperature °C	P [KW]	Duty cycle	Time to reach the MPP
75	*155.4*	*0.7684*	*1.723*
50	*164.4*	*0.7832*	*0.8825*
25	*195.3*	*0.7285*	*0.8375*
0	*219.9*	*0.7223*	*0.9769*

It is evident that GWO can track objects quickly, whereas PSO can monitor maximum power points with more accuracy.

Finally, the simulation results for the third scenario are performed using diverse scenarios of 1000, 800, 600, 400, and 200 w/m^2 under uniform irradiance. The accompanying tables show that MPP can be tracked by both GWO and PSO in a variety of irradiation conditions. From a power point of view, the GWO algorithm performs better than the PSO method when tracking speed. On the other hand, owing of its higher MPPT accuracy, PSO outperforms GWO.

Table 4. PSO simulation results under uniform irradiance At 25 °C.

Irradiance w/m^2	P [KW]	Duty cycle	Time to reach the MPP
1000	*200.2*	*0.7451*	*1.442*
800	*160.6*	*0.7055*	*1.471*
600	*121.2*	*0.6606*	*1.983*
400	*81.37*	*0.5951*	*0.963*
200	*39.97*	*0.4357*	*1.559*

Table 5. GWO simulation results under uniform irradiance At 25 °C.

Irradiance w/m^2	P [KW]	Duty cycle	Time to reach the MPP
1000	*196.0*	*0.7300*	*0.8499*
800	*161.1*	*0.7087*	*0.9826*
600	*109.5*	*0.6211*	*0.8396*
400	*80.96*	*0.5829*	*1.126*
200	*34.53*	*0.5000*	*0.9794*

V. Conclusion

The paper compares Particle Swarm Optimization (PSO) and Grey Wolf Optimization (GWO), two optimization techniques, in the context of Maximum Power Point Tracking (MPPT) for photovoltaic (PV) systems. The study highlights the trade-offs between tracking accuracy, speed, and convenience of use, emphasizing the advantages and disadvantages of both PSO and GWO in MPPT for PV systems. It also acknowledges the importance of choosing the right parameters to achieve the best possible performance. The results of the simulation show that both the PSO and GWO approaches can correctly follow the MPP under all conditions. Notably, the GWO algorithm performed better than the PSO algorithm in terms of the perfect tracking speed. PSO, however, has many advantages, including exceptional precision and simplicity of use. It is crucial to keep in mind, nevertheless, that the PSO's optimization performance may be influenced by the parameters selected.

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